This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

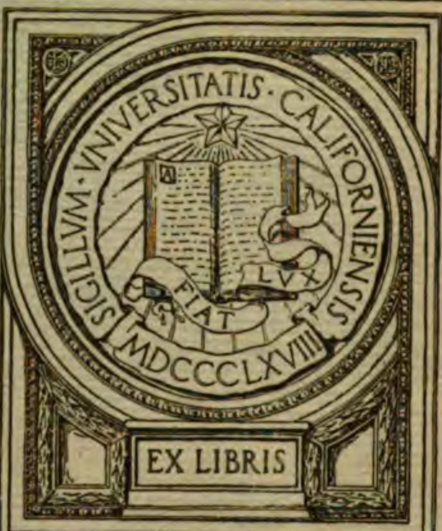
Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

SD
409
Oz

UC-NRLF
B 3 955 615

REFORESTATION OF THE CEDAR RIVER WATER SHED

By R. G. Ober and H. C. Johnson
PROCEEDINGS - JULY, 1915
Pacific Northwest Society of
Engineers



EX LIBRIS

Agric.-Forestry. Main Library

PACIFIC NORTHWEST SOCIETY of ENGINEERS

INSTITUTED 1902

PROCEEDINGS—VOL. XIV. NO. 2

Reforestation of the Cedar River Water Shed

By R. H. OBER and H. C. JOHNSON

JULY, 1915

UNIV. OF CALIFORNIA

Published by the Society at Seattle, Washington

Copyrighted 1915, by the
Pacific Northwest Society of Engineers

Officers and Directors

1915

OFFICERS

President	MARVIN CHASE
First Vice-President	D. W. McMORRIS
Second Vice-President	A. P. DENTON
Third Vice-President	A. S. DOWNEY
Secretary	JESSE A. JACKSON
Treasurer	WENDELL N. CHASE
Librarian	C. E. HILL

DIRECTORS

J. D. BLACKWELL
ALMON H. FULLER
GEO. P. JAMES
MILNOR ROBERTS
R. H. THOMSON
T. A. NOBLE
GEO. A. KYLE
J. J. CRYDERMAN

PAPERS PUBLISHED

"STRENGTH OF PILES"—C. S. Bihler. Vol. I, No. 1. Price 25 cents.

"COMPARATIVE TEST OF YELLOW PINE AND PUGET SOUND FIR"—F. W. Hibbs. Vol. I, No. 2. Price 50 cents.

"THE TEREDO AND THE LIMITATIONS OF ITS ACTION"—F. W. D. Holbrook. Vol. I, No. 3. Price 25 cents.

"CONCRETE AND ITS USES"—James E .Blackwell. Vol. I, No. 4. Price 25 cents.

"CORROSION OF IRON AND STEEL"—C. E. Fowler. Vol. I, No. 5. Price 25 cents.

"THE IMPROVEMENT OF GRAYS HARBOR, WASH."—J. M. Clapp. Vol. I, No. 6. Price 25 cents.

"CALCULATING INSTRUMENTS"—C. T. Morris. Vol. II, No. 1. Price 25 cents.

"FILING AND INDEXING DRAWING OFFICE RECORDS"—A. V. Bouillon. Vol. II, No. 3. Price 25 cents.

"MUNICIPAL IMPROVEMENTS, VICTORIA, B. C."—C. H. Topp, City Engineer. Vol. II, No. 5. Price 25 cents.

"WORK OF THE SEATTLE AND LAKE WASHINGTON WATERWAY COMPANY"—C. H. Rollins, Chief Engineer, Vol. III, No. 1. Price 25 cents.

"THE ELECTRICAL EQUIPMENT AND DISTRIBUTING SYSTEM OF THE SEATTLE ELECTRIC COMPANY"—Elbert G. Allen, Electrical Engineer. Vol. III, No. 2. Price 25 cents.

"STREET GRADES IN SEATTLE"—A. H. Dimock, Assistant City Engineer. Vol. III, No. 3. Price 25 cents.

"A GRAPHIC METHOD FOR CRANK EFFORT DIAGRAMS"—Frank W. Hibbs. Vol. III, No. 4. Price 25 cents.

"CO-OPERATION OF STATE AND FEDERAL GOVERNMENTS IN TOPOGRAPHIC AND HYDRAULIC SURVEYS"—T. A. Noble, Engr. U. S. Geological Survey. Vol. III, No. 5. Price 25 cents.

"SECOND ANNUAL CONVENTION"—"THE FIELD AND WORK OF THE ENGINEER AND ARCHITECT IN THE NORTHWEST"—C. E. Fowler, Pres. "THE CEDAR RIVER MUNICIPAL LIGHT PLANT"—R. H. Thomson, Past Pres. "AN AMERICAN ENGINEER IN EUROPE"—Geo. F. Cotterill, Con. Engr. Vol. IV, No. 1. Price 50 cents.

"THE USE OF TIMBER IN BRIDGE CONSTRUCTION"—Charles Evan Fowler, C. E. Vol. V, No. 1. Price 25 cents.

"CONCRETE-STEEL DESIGN AND CONSTRUCTION"—C. F. Graff. Vol. V, No. 2. Price 50 cents.

"MUNICIPAL LIGHT AND POWER IN TACOMA, WASHINGTON"—Howard Joslyn. Vol. V, No. 3. Price 25 cents.

"THE DESIGN AND CONSTRUCTION OF TALL CHIMNEYS OF REINFORCED CONCRETE"—George Cotner Mason. Vol. V, No. 4. Price 25 cents.

Agric.-Forestry. Main Library

UNIV. OF CALIFORNIA

Pacific Northwest Society of Engineers

INSTITUTED 1902

PAPERS AND DISCUSSIONS

Reforestation of the Cedar River Watershed.

BY R. H. OBER. CONSULTING ENGINEER,
AND
H. C. JOHNSON, FOREST ENGINEER.

DESCRIPTION OF WATERSHED.

The term "watershed," in its strict signification, means the edge of a river basin; the line, or "divide" separating the water flowing into two different rivers or river basins. The watershed, as thus defined, limits, or forms the boundary of, its catchment area, as used in hydraulic engineering.

As applied to the watershed of Cedar River, local custom, and the terms of the ordinances and enactments of the City of Seattle, have given to the words "Cedar River Watershed" a wider significance. These words, in this sense and as uniformly used in this report, mean the entire area of land drained by Cedar River and all its tributaries, from the summit of the Cascade Mountains down to the intake of the pipe lines which convey to the City of Seattle the water from Cedar River to the watermains and reservoirs in the city.

This intake is located at a point about twenty-three miles in an air line southeasterly from Pioneer Place, at what is known as Landsburg. From the lowest point of the watershed at Landsburg, at an elevation of 540 feet above city datum, to the highest point, in the vicinity of Yakima Pass at the summit of the Cascade Mountains, at an elevation of about 5300 feet above city datum, the length of the watershed, measured in an air line, is about twenty-five miles, and its area is 137 square miles. Following the sinuousities of the river, this distance is thirty-one miles, in which distance the waters of the river fall 4760 feet. Of this fall, the greater part occurs in the first few miles of the river's course, where the streams are torrential in character, in many places plunging over cliffs of considerable height. As the distance from the summit of the mountains increases, however, the

345004

fall becomes less rapid and at a point about fourteen miles from the summit of the mountains the current of the river is checked by the waters of Cedar Lake.

Cedar Lake has a length of about three and one-half miles, an average width of about one-half mile, and is of great depth. The surface of the lake originally was at an average elevation of about 1530 feet above sea level. The construction of the timber crib dam near the outlet of the lake, in 1903-4, has resulted in the raising of the water about seventeen feet.

Leaving the dam at the outlet of Cedar Lake, the river flows through a deep and narrow canyon, having a very precipitous descent of 600 feet in a distance of three and one-half miles. At the foot of this descent is located the Municipal light and power plant of the City of Seattle.

After leaving the power plant, at an elevation of 920 feet above sea level, Cedar River flows through a fairly level valley for a distance of about twelve miles to Landsburg, at an elevation of about 540 feet above sea level.

The watershed is divided naturally into two main divisions, referred to in this report as the upper watershed and the lower watershed. The upper watershed extends from the site of the proposed masonry dam, at a point on Cedar River about two miles below the outlet of Cedar Lake up to the summit of the Cascade Mountains, covering an area of about eighty-three square miles; and the lower watershed extends from the site of the proposed masonry dam down to Landsburg, covering an area of about fifty-four square miles.

It will be noticed that the upper watershed is practically the watershed of Cedar Lake, which constitutes the lowest point of this upper watershed. It is characterized by steep and precipitous mountain slopes rising abruptly from the shores of Cedar Lake and from the narrow valley of Cedar River, and of Rex River, to the summits of the flanking ridges on each side. In many places there are found extensive areas covered by masses of rock, either in the form of cliffs or what are known as rock slides. Near the summit of some of the mountains there are open parks and grassy meadows, in which but little timber is found; but, aside from the barren spots, the entire area is covered by a heavy growth of timber. This timber varies in character from stands of Douglas Fir in the valleys, where a single tree often reaches a height of 250 feet, with a diameter of six feet at the base, to the scattering and scrubby growth of what is known as upper-slope type of timber, upon the summits of the mountains. It is estimated that the present stand of commercially valuable timber upon this upper watershed exceeds in amount one billion feet, board measure.

The lower watershed, although bounded upon the north, east and southeast by mountain ridges, is what may be characterized as rolling or bench land. The timber which originally covered the lands in this lower watershed was, generally speaking, of a larger growth and more valuable than that upon the upper watershed, by reason of the fact that the lower elevation is more favorable to timber growth and affords a longer growing season.

By reason of its proximity to the railroads which were first built into this country, and of its general accessibility, logging operations in this lower watershed were begun at an early period and a considerable portion of this area has now been denuded of timber and is ready for reforestation.

Policy of the City of Seattle in the Acquisition of Lands in the Watershed

The acquisition of lands in the Cedar River watershed by the City of Seattle, in connection with the construction of the Cedar River water supply system and the municipal light and power plant, and for the purpose of protecting the water supply from pollution, was undertaken by the city about thirteen years ago, beginning in a small way and extending from year to year as time went on, until there is now owned by the City of Seattle, within the watershed, a total area of 37,982 acres, or 59.39 square miles.

The policy of the city in acquiring the lands within the watershed for the purpose of protecting its water supply is one the wisdom of which has been demonstrated by the results obtained up to this time, and the continuation of this policy in the acquisition of the remainder of the land in the watershed will result in giving the City of Seattle an assurance of a continuation of an adequate supply of pure and wholesome water not surpassed by that of any city in the world.

At the time the acquisition of these lands was first undertaken by the city there were located within the lower watershed several saw mills and logging companies which had been operating there for a number of years. The city at that time had not sufficient money to undertake the purchase of the timber belonging to these mills and logging companies, or of the mills and equipment of the companies; and for that reason, the operations of logging and cutting of timber have been carried on in this lower watershed by private parties up to the present time and are still being carried on in such manner. The city has been successful, however, in the regulation of these operations so that the danger to the water supply has been reduced to a minimum and the operation of the camps and of the mills has been carried on in a reasonably sanitary manner.

Within the upper watershed, however, extending from the site of the masonry dam at Camp 2, including Cedar Lake and reaching to the summit of the Cascade Mountains, no logging operations had been commenced at the time of the establishment of the city's policy to acquire the land in the Cedar River watershed, and up to this time the City of Seattle has been successful in preventing the establishment of logging camps and saw mills in this territory. In order to prevent the establishment of these camps it has been necessary for the city to purchase, in many instances, not only the land, but also the timber standing thereon. In this manner there has been acquired timber having an estimated value at the present time of nearly $700,000.00. The total cost of the acquiring of all the land and timber in the watershed up to this time, exclusive of cost of surveys, appraisals and court costs, is something over $600,000.00, or nearly $100,000.00 less than the estimated cost of the timber alone. Adding the cost of survey, appraisals, timber cruising and court costs, it is found that the value of the timber belonging to the city is approximately equal to the cost of acquiring both land and timber up to the present time.

If the established policy of the city, as approved by the voters in authorizing the issuance of bonds in the amount of $1,000,000.00 for the purpose of acquiring the land in the watershed, be continued by the city in the future in the acquisition of the remaining land and timber in the upper watershed, it should result finally in the obtaining of the entire watershed without material cost to the city. In other words, the increase in stumpage value of timber should be sufficient to pay for the cost of acquiring the land. In order to realize these values, however, it will be necessary, under proper sanitary regulations, to cut and market the timber. Upon the removal of this timber there arises the problem of determining the best use to be made of the logged-off lands.

Necessity for Adoption of a Fixed Policy and Definite Plan for Management of Lands in the Watershed

The operations of the logging companies in the lower watershed have already resulted in the denuding of large areas of land once covered with a heavy growth of valuable timber. The greater part of this logged-off land is now the property of the city. It was acquired for the purpose of protecting the water supply of the city from pollution, and in order to carry out that purpose the acquisition of the lands was amply justified. In its present state it does not constitute anything of value to the city except for the particular use and purpose of protecting the purity of the water supply. It may have a potential money value, however, dependent upon the use which can be made of it.

If left to itself this logged-off land will be covered by a growth of weeds and a scattering growth of inferior timber and will remain non-productive and of practically no value to the community and to the state. It is evident that a policy of this kind, if applied to the watersheds which constitute the sources of supply of all of the large cities of the state, would result in the withdrawal of enormous areas of land from productive use, would cause a great economic loss, and would prevent the proper upbuilding and development of the state.

The problem is to determine the best use to be made of these logged-off lands within the watershed, having due regard to the necessity of protecting the water supply.

It is evident that the use of these lands for agricultural or dairy purposes, if they were adapted to that use, would be one which would not be consistent with the purpose for which they were acquired, for the reason that it would mean the occupation of the land by large numbers of animals and the introduction of a resident population with consequent danger of pollution of the water supply.

In the same way, the development of any manufacturing or industrial enterprise upon these lands would be a menace to the purity of the water supply.

The use of these lands, however, for the growing of timber does not require the continued residence of any large number of men, nor the establishment of a resident population with its attendant dangers, and would result in a great benefit to the quality of the water supply of the city, as well as in conserving that water supply and, to some extent, in regulating the run off of the streams. If a growth of valuable timber upon these lands can be secured at a low cost within a reasonable time and under conditions which would warrant the incurring of the necessary expense from an investment standpoint, with a reasonable likelihood of a profitable return to the city, it would seem to justify the undertaking. At least, investigations and experiments for the purpose of determining the advisability of adopting a plan for the ultimate reforestation of all of the lands within the watershed should be made and a fixed policy should be adopted by the city for the handling of the lands in the watershed.

The production of a growth of valuable timber on this land would result in the creation of an asset of enormous value to the community at large in the place of a doubtful asset, or possibly a liability, if no systematic or organized effort is made for the reforestation of these lands and the area is allowed to grow up to weeds and a scattering growth of inferior timber having but little value. In other words, the adoption and carrying out of a fixed policy and a definite plan will create values where otherwise they would not exist.

In order to determine the feasibility and advisability of adopting such a plan for the reforestation of this area, a careful study of the watershed with a view to its use for this particular purpose has been carried on for a period of four years. During this time an exhaustive examination of the entire area of the lower watershed has been made for the purpose of obtaining the data used in the preparation of this report, covering all of the features of the reforestation of the lower watershed.

No report is made as to the reforestation of the upper watershed at this time, for the reason that this would await the advance of logging operations into this area and should receive more study than has yet been given to it.

~~~

REFORESTATION OF LOWER WATERSHED

SECTION I.

General Description.

The lands dealt with in this plan all lie west of the divide, between the streams flowing into the area above the new masonry dam and those flowing into Cedar River below it. That is, this area is that described in the introduction as the lower watershed, and it comprises a total area of 36,322 acres, or 56.8 square miles. This area is somewhat larger than the actual drainage basin, as it was necessary to obtain the entire area of every "forty" through which the crest line passed.

In this area the lands already logged-off (at the end of the year 1912), comprised 15,752 acres. About 780 acres, however, are railroad rights-of-way, and other such-like areas, which leaves a total area of 14,972 acres or 23.4 square miles of lands at present in need of reforestation. A most vitally important point, as can be noticed on the map, is that these logged-off lands are not in small scattered patches, with timber around them, but they lie in large, solid blocks, covering many square miles, with no timber near at hand. This eliminates the chance of the area seeding up from the adjacent forest, and as no live trees are left on the greater part of this area and as the fires that have swept over here for the past eight or ten years have entirely destroyed any seed that might have remained in the soil, the only method by which a new forest growth can be obtained is by some artificial means. The best proof that such means must be used is shown by the fact that, on actual counts made on some areas in Taylor Creek, and also near Barneston, on areas covering from one-quarter to one-half a square mile, not one single young tree nor seedling of Douglas fir nor any other commercial species was found,
~~~

and that, after having had from eight to ten years, since being logged, in which to show evidences of a new forest coming up.

The remaining 20,670 acres, or 32.2 square miles, is at present still timbered, but the two logging companies now operating are denuding this at the rate of about 800 acres every year. It is estimated that on about seven square miles of this area the timber is too poor to be cut, so that, eliminating this, it means that in from 15 to 20 years there will be about 16,200 acres, or 25.3 square miles, more of logged-off lands, which, present conditions being allowed to continue, will also become a barren waste. This brings the total area up to 31,200 acres, or 48.75 square miles, on which there is a present or will be a future need for a plan of reforestation.

NATURAL DIVISIONS.—The entire area falls naturally into four main divisions according to the four drainage basins in which it lies. These divisions are as follows:

DIVISION No. 1.—The Rock Creek, Webster Creek, and Walsh Lake drainage basin.

DIVISION No. 2.—The drainage basin of William's Creek and Cedar River above Taylor Creek.

DIVISION No. 3.—The Taylor Creek drainage basin.

DIVISION No. 4.—The narrow strip of land draining into Cedar River from both sides, and lying below Taylor Creek. The location of these four divisions is shown on the map.

It is of great advantage to divide the area in this manner, as the entire tract is too large and presents too many and varied conditions to admit of specific handling as a unit. It is not necessary here to give detailed descriptions of each division, and it is sufficient to state that, for the present, DIVISIONS Nos. 1 and 2 are the most important to consider as they have the best site and soil qualities and the best economic situations, which means that they will yield the best and quickest returns. Also they can be more advantageously worked and are more in need of it than is the rest of the area.

A close and detailed study of the entire area was made for data along the lines of such natural factors as govern or influence the work and a brief description of such factors follows:

TOPOGRAPHY.—The elevation varies from 540 feet above sea level, at Landsburg, to as high as 4000 feet at the headwaters of Taylor Creek. However, nearly 90% of the present logged-off lands lie below the 1200 feet contour, while where future logging will be done, but little will be above the 2200-feet contour. In fact, on the whole 31,200 acres as planned for, over 66% lies below the 1600-foot level, and practically all of it below the 2200-foot level. As elevation is one of the main factors governing both the rapidity and quality of tree growth, this natural condition is here a most advantageous feature.

Exposure, too, is of great importance. Here, the greater part of the land is so gently sloping, or else level, that it cannot be said to have any definite exposure, but receives sunlight all the day. As for the steep hillsides, about 75% of such land has a south or southwestern exposure, which is, of course, the best, and so it may be said that, from this point, the entire area is favorably situated.

The land itself may be classed as bottom land, bench land, gently rolling and mountainous. The amount of bottom land is, however, practically negligible, while that which is classed as mountainous, or exceeding 20% in slope, is less than 15% of the area. And the work should be done on the latter class as much for protection against erosion as for the financial returns. There are several large areas of well-drained bench land, but by far the greater part of the whole area may be classed as rolling or gently sloping. And it is these last two classes of land, with their deep, porous soils, that yield the very best growth of fir, as was evidenced by the former growth.

CLIMATE.—As most of the species used in this work would be natives of this region, it is self-evident that they can live in this climate and the main study was to see just how advantageous the climatic factors would be. Rainfall is, of course, the most important. Readings for the past ten years give an average annual fall at Landsburg of 52 inches while at Cedar Lake it reached an average of 112 inches. This is more than ample for the best growth.

The relative humidity is very great, which favors a rapid growth. Extremes of temperature are not great, as it rarely goes as low as zero, nor much above 100° F., and such extremes are not at all detrimental. The length of the growing season is very long, beginning early in April and lasting well up into October. This gives a season of about seven months, which, combined with the other favorable factors, insures a large annual growth.

The natural climatic factors which might be considered harmful, such as wind, frost, drought and heavy snow, are nowhere severe enough to afford any real menace.

SOIL CONDITIONS.—The soils found here are loam, clay, sand and gravel, and rock, or rather, varying admixtures of these constituents, and in some places there is some swamp land. Where the soil is rich and loamy it will be best to plant eastern hardwoods, both because of the chemical composition of the soil and of its moisture-holding qualities. On the swampy areas the soil, while very moist, is not acid, and there spruce and cedar may be used or possibly ash or cottonwood. But by far the greater part of the area is sandy soil, with varying admixtures of gravel and rock. This soil is porous and well drained, good qualities for the growth of fir; deep, so that the trees will have a good root development, and, while rich enough in all the mineral elements required by Douglas fir, is still not rich enough to support a rank weed growth that would kill out the young trees.

GROUND COVER.—Under this heading, two classes may be considered; first, the weed growth that has come up; second, the debris, down logs and snags left after lumbering. Needless to say, this applies only to the lands already logged-off, as ground cover is of no importance on the lands still timbered. The larger part of the area is covered with a light growth of salal and ferns, which is not heavy enough to hinder the growth of young trees when set out, but which might make it impossible to sow seed directly. Parts of the area, especially near Barneston, are practically free from weed growth and there seed sowing may be done. On the other hand, some portions, particularly up Taylor Creek, have such a dense growth of salmonberry, fire-weed and ferns that they present a serious problem, and it will probably be best to burn them over before working on them.

The other class of ground cover, as down logs, debris and old snags, are important only in so far as they make the work of the men harder, thereby increasing the cost, and also as they increase the fire risk. Such debris occurs, in greater or less density, over the entire area, but is thick enough to cause serious trouble only in some parts of Taylor Creek valley. On some portions there are also thick stands of young pole-woods, which have been killed, and these will have to be cut down and burned, which will be rather expensive, but they are of rare occurrence.

SITE QUALITIES.—By site quality is meant the capacity or ability of the site to produce tree growth. Three site qualities are recognized in this country, and the difference of these qualities is determined by the occurrence and combination of all natural factors, such as soil, elevation, exposure, climate, etc., which have previously been discussed. Also the quality of a site depends upon the species which is to be grown upon it, as for example, a deep, light, porous, sandy, well-drained soil, which, at low elevation, would constitute a No. 1 quality for Douglas fir, would only be a No. 3 quality for spruce or some of the eastern hardwoods. However, the areas best fitted for hardwoods, and also spruce and cedar, were first determined and the following study and discussion of site qualities refers only to sites intended for the growth of Douglas fir and such species as may be associated with it, as white pine and a few others, and this includes practically 90% of the entire area. The importance of knowing the areas of these different site qualities can be seen, when it has been calculated that, at 100 years, a No. 1 quality site will produce 100,000 feet B. M. per acre, a No. 2 quality site only 66,000 feet B. M. and a No. 3 quality site only 49,000 feet B. M. per acre. This is of the utmost importance when it comes to forecasting future results.

Site qualities were first determined on timbered areas, mainly by a study of the heights of average trees, for it is a law that, in even-aged stands the height of an average tree varies directly as the quality of the site; that is, the taller the tree, the better the site qualiy. At the same time the diameter of trees were measured and all natural factors, with their influences, were noted. Similarly situated areas were then found on the logged-off lands and the diameters of the stumps were measured as a check. Comparison of the surrounding lands was then made and the effect of differences in soil conditions, exposure, elevation, etc., were noted and the proportion in which they affected the quality. In this way, and from a knowledge of how different combinations of conditions affect tree growth, the different site qualities were determined.

These qualities were then checked again by a comparison with the general site qualities for Douglas fir in western Washington and Oregon as determined by the U. S. Forest Service. This general classification is as follows: No. 1 quality occurs below 1000-foot elevation; soil loamy, mixed with sand, clay or gravel, deep and well drained; land generally bench land or gently sloping. This site occurs mainly in the valleys of larger rivers and would generally be called agricultural land. No. 2 quality occurs generally from 800 to 1300 feet, though sometimes as high as 2000 feet. Soil is generally of a sandy or gravelly nature, from shallow to medium depth, and land is gently sloping or even steep. This site occurs mainly in the foothill regions. No. 3 quality occurs above the 1500-foot elevation. Soil is shallow, gravelly sand, with rocky subsoil and many rock outcrops. This site generally occurs at higher altitudes and with rough topography.

Of course, in classifying the different site qualities there were many cases where one would merge into another and it would be hard to tell to which quality it did belong. In such cases it was the invariable rule to put all lands in doubt into the next lower quality so that any error that might occur would be one of safety, and that would insure conservatism in the figures.

SECTION II.

Methods of Originating New Forest.

In considering this subject it is first necessary to distinguish between the two main classes of land, namely: those now logged-off and barren where the new forest must, of necessity, be started by some artificial means, and those lands which are still timbered, but which will be logged in the future, where the methods used may be either artificial or natural or a combination of both.

ON LANDS ALREADY LOGGED-OFF.—On these lands there are two entirely separate methods of starting the forest. First, by a direct sowing of seed; second, by the setting out of young trees. First, the direct sowing of seed will be discussed.

DIRECT SOWING OF SEED.—As this work will not be done extensively enough to warrant building a conery, the seed will be bought in the open market, at a price varying from $1.75 to $2.25 per pound. Good, clean Douglas fir seed contains about 43,000 seeds per pound, with a germinating percentage of about 55%, according to tests made, so that an estimate of 20,000 vital seeds per pound is conservative. Three methods of direct sowing of seed can be used, the seed-spot method, the strip method, and broadcast sowing. However, under the conditions existing here, only the seed-spot method is applicable, and the following description and cost data applies only to it.

In this work, three men form a crew, two preparing the spots and one sowing seed. The spot is scraped bare, from 12 to 20 inches square and 20 to 30 seed are dropped in, a little earth kicked over them and lightly pressed down. The spots should be spaced about 6 feet by 6 feet, making 1210 spots per acre. Closer spacing would be too expensive and further spacing would hardly yield good enough results. One crew of three men should prepare and sow from 3000 to 4200 spots, or from 2½ to 3½ acres per day, with a spacing of 6 feet by 6 feet, the area covered varying accordingly as the amount of down timber and debris hinders the men.

The main points of advantage of this method are the following: The cost of the seed is small and the work can be done rapidly, making the whole operation a cheap one. The preparation of the spot insures the seed coming into contact with the mineral soil, a necessary requirement for its germination. Some choice is given in preparing the spots in the most favorable locations. The results can be watched and points obtained for future guidance. Above all, there is the big advantage that always occurs when a forest comes up with a certain degree of regularity in the spacing of the trees, instead of in a haphazard form. All of these points indicate that the method may be used on some parts of the area.

The best season for this seed-sowing work is in the fall, as then the seeds get plenty of moisture and in spring the young seedlings have attained a good start before having to face the summer, whereas if the sowing were done in the spring an early hot dry spell might kill everything. The ravages of birds and rodents may do a great deal of damage and must be guarded against. As a protection against birds the seeds may be coated with red lead, while poisoned grain, scattered or placed over the area, is the best protection against the rodents. The cost of this is very little.

The following are general costs for seed-spot work: Spots spaced 6 feet by 6 feet or 1,210 spots per acre. Seed used, an average of 25 per spot or 0.7 pounds per acre, costing $1.40. Administration $.50 per acre.

Three men, at $2.75 per day, to plant from 2½ to 3½ acres per day, according to the roughness of the ground. Total costs will then run from $4.25 per acre to $5.20 per acre. If properly done, on areas favorable for the work, the results should be somewhat better than one seedling per spot on the average. The broadcast and strip methods require so much seed and preparation as to render the cost too excessive for the results secured, and will not be used here.

OUTPLANTING OF NURSERY STOCK.—However, by far the greater part of the area must be stocked by the setting out of young trees. The only reasons in favor of seed sowing are speed, and so covering a large area in a season, and the slightly cheaper cost. Against this must be set the risk that the work may not prove successful and also the inability of the method to insure certain silvicultural advantages that can be obtained by setting out young trees. Some of these advantages are as follows, and all are important: The young stock, two years old when set out, has its root system well developed and can take hold in the soil at once, thus insuring growth. Correct and regular spacing is obtained, which means a full utilization of the productive power of the soil, a forcing of the height growth, and the formation of a clean bole, and the securing of the maximum yield for each site quality. An absolute even age of the new forest is secured, thin spots are obviated, and the young trees can be easily located and their development watched and tended. Future treatment of the stand is made easier and the forecasting of future results and returns can be done with a greater degree of certainty. And especially where it will be deemed best, as will often be the case, to have an admixture of two or three species on the same area, some perhaps several years older than others, the nursery stock offers the only method of securing such a forest. And, added to all these advantages are the facts, first, that on about 70% of the area, or 11,000 acres, it will be absolutely necessary to set out young trees, as the heavy weed growth precludes any chance of seed sowing, and second, that seed sowing cannot be used for some of the species desired, but the young trees themselves must be set out .

So, seeing that most of the work would be done by setting out nursery stock, a plan was drawn for the location of a nursery at Cedar Falls. The city already owns a piece of land there, admirably adapted to the purpose, with good soil, level, and well drained, southwestern exposure, and centrally located for transportation purposes to the entire area and also to the upper watershed. The plan was drawn for a nursery capable of raising 250,000 trees annually, and it admits of being enlarged to a capacity of half a million trees if desired. The stock to be grown, of Douglas fir, will probably be what is known as 1-1 stock; that is, one year in the seed bed and one year in the transplant bed. Other species will, of course, be grown so as to give the best results for them. It is estimated that such stock can be raised at a cost of not to exceed $4.00 per thousand trees.

The work of outplanting may be done in either the fall or spring, but preferably in the fall, for the following advantageous reasons: The loose earth around the plants is packed in firmly during the winter, and the trees set in more firmly; if the root systems are injured during the outplanting they have a chance to heal during winter; if the species are early budding ones, or if there should be an early spring, the plants are already to take advantage of it; labor is cheaper and easier to obtain in the fall, and, above all, plenty of moisture is assured at the time it is most needed.

In the work of outplanting, the plants are transported from the nursery to the field operations, either by wagon or packed in boxes on pack horses. They are then "heeled in;" that is, put under shade or protection and the roots covered over with moist earth and straw, and are distributed to the men as the work progresses. Each man carries with him half a day's supply of plants, renewing it at noon and on the average it may be figured that 400 plants a day should be set out for each man in the crew; an estimate which makes full allowance for bad weather, for in good weather the average should be fully 500 plants per man per day.

The most important point in the outplanting is the determination of the correct distance for spacing the trees, and several important factors govern this. From a silvicultural standpoint close spacing is desirable, as then a rapid height growth is forced pruning of the dead limbs occurs earlier and consequently a greater clear length of the bole is obtained and more and better quality of the product is the result. Also, the closer the spacing, the earlier a complete crown cover is obtained, with the consequent protection of the soil. Against this must be balanced the financial aspect of the subject. The closer the spacing, the greater the initial investment, both for the stock set out and for the cost of labor, and this initial investment must bear interest for a period of 70 to 90 years. As every dollar invested and figured at 4½% compound interest—the rate at which the city figures its investments—will amount in that time to from $21.78 to $52.54, it will be seen that close calculations must be made as to how large the initial investment can be and still leave a profit. And still another angle of view is the fact that here thinnings can be made after 40 years and their returns must be calculated to determine whether or not to space close, at a greater cost, and obtain the revenue from the thinnings, or not to take the chance. It is the author's opinion that there is a splendid future market in this region for these thinnings, as is discussed later under "Economic Conditions," and that consequently close spacing is advisable. This means generally a spacing of 7 feet by 7 feet or 6 feet by 8 feet, making approximately 900 plants per acre and a good part of the area can be planted as close as 6 feet by 6 feet or 1210 plants per acre, while in some parts it may be best to space as far apart as 8 feet by 8 feet, or 680 plants per acre.

In computing the costs for this work, the estimates were purposely made high so as to be conservative, and were based on the following terms: Cost of growing in nursery, $4.00 per thousand. Transportation to field, $1.00 per thousand, very high. Administration costs, $.50 per acre. Labor, $2.75 per man per day, and allowing an average of 400 plants per man per day, on this basis the following table gives the cost of such work:

Table of Unit Cost per Acre for Outplanting 1—1 Nursery Stock.

Spacing distance in field	No. of plants per A.	Cost of plants at nursery	Cost of hauling to field	Labor Cost of setting out	Administration cost	Total cost per acre
6′ x 6′	1,210	$4.84	$1.21	$8.32	$0.50	$14.87
7′ x 7′	890	3.56	.89	6.13	.50	11.08
8′ x 8′	680	2.72	.68	4.67	.50	8.57

ON LANDS STILL TIMBERED BUT TO BE LOGGED.—These lands, however, present an entirely different problem from those already logged-off. Here there is the choice between cutting the area clean and then reforesting by one of the two artificial methods already described, or to use the natural method of leaving seed trees while logging. From a silvicultural standpoint, clear cutting and artificial reforestation may be somewhat better, but economic conditions favor the leaving of seed trees. The great amount of land now barren which must be artificially restocked will require the concentration of such work for several years, which means that if the 800 acres now being annually logged should be cut clean, they would have to lie unproductive until the present barren areas are reforested, after which they can be worked upon. By leaving seed trees, however, the reforesting of this land can be immediately started, and with the other work going on on the other areas at the same time the entire area can soon be brought to a state of production. Another point is the fact that these timbered areas are mostly upon the poorer site qualities, so that with their lower yield and lower expectation value, it is desirable to keep the initial investment as low as possible.

A Douglas fir tree can scatter its seed to a distance of about twice its height. A tree 150 feet high can therefore seed up approximately 1.6 acres, which would require the leaving of about 25 seed trees on a "forty." Such a tree, 150 feet high and 38 inches in diameter, would contain on the average 2000 feet B. M., which at $2.50 per M., makes the cost per acre $3.13. However, it is generally possible to select trees fit for this purpose of seeding, which, because of defect, such as conk, crook, rot, fork, etc., contain only poor lumber and should be charged for at a much lower stumpage rate.

The administrative cost of selecting such trees would be about $.10 per acre. Some care must be used in logging to protect these trees and the additional cost to the logging operation is figured at $1.50 per acre. Also, when the slash is burned, care must be taken to protect these trees, and the cost of this is figured at $.75 per acre. This gives a total cost for the seed tree method of $5.48 per acre, which is a maximum.

The method is therefore cheap, takes no time for labor outside of the regular operations of logging and has the big advantage that if fire should kill the first growth, the source of seed supply is still present and a new growth can be obtained at no extra cost. Danger from windfall in this particular locality is very small, and if proper care is used in burning the slash, the fire menace to the seed trees is also small. With these points, in addition to the need for speed in the work for reforesting, it is advised that this method be used wherever possible on the lands that are to be logged in the future.

It is probable that under this method bare spaces may occur, where no seed had fallen, or larger spaces may occur, due to the windfall of the seed trees. However, such spaces could generally be planted up by broadcast sowing of seed, or if necessary, by the outplanting of nursery stock, and this objection is not sufficient to overrule the advantages of the method in this particular case.

SECTION III.

Species to Be Used.

The choice of the different species to be used in this work depends upon two points, which may be called the natural and artificial suitability of the species. By natural suitability is meant the degree of adaptation of the tree to the climatic and soil conditions under which it must grow. It must be able to live on the minimum amount of rainfall, grow and lignify in the growing season, stand the changes of temperature, be adapted to the soil and also be able to withstand the winters and frost and be able to protect itself against the diseases of this region. These general conditions were described in Section 1.

By artificial suitability is meant the economic and silvicultural characteristics of the species. The species must be capable of growing fast enough to yield a merchantable product by the end of the rotation, in this case about 70 years, and this product must be of good quality, sound and in every way acceptable to the trade and able to command a good price. Also the species must be such that the products removed as thinnings in the earlier periods should also fill the above requirements. In addition, the trees must be able to adapt themselves to the desired silvicultural method of handling ;that is, to be first started by the method desired and then to be cut and again started as desired. Also they must be such as to be able to be put into such mixtures of species as may be desired.

Of course, all the species now growing here are naturally suited, but not necessarily so from a commercial standpoint. A careful study of all of these has been made and the use of the following species is recommended:

DOUGLAS FIR (Pseudotsuga taxifolia).—This species will be used more than all others combined. The natural conditions are admirably suited to it and it should make a very fast growth, yielding a large amount of saw timber by the end of the rotation. It is the most useful tree of the Northwest, its lumber being in demand for practically all uses, and finding a ready market. It is especially valuable for this work since it can yield in the form of early thinnings large quantities of mining timbers, piling, poles, railroad ties, etc. Silviculturally it is also well adapted for the work, as it can be started easily, and will grow well either in pure stands or in mixture with other species.

Of the other native conifers SITKA SPRUCE (Picea sitchensis) and WESTERN RED CEDAR (Thuja Plicata) will prove useful on the swampy areas. The spruce is a fast grower, a prolific seeder for future reproduction, and does well in pure stands. The wood is valuable for cooperage, finishing, doors and pulp wood and the yield should be fairly large by the end of the rotation. Cedar will do well and its products are valuable, the only drawback being that the rate of growth is rather slow. However, it will be best to use it, at least on some of the swamps. WESTERN WHITE PINE (Pinus monticola). This native white pine grows well in mixture with fir, and has the same soil requirements. The wood is valuable and, though the tree is of slower growth than fir, it would be best to plant considerable of this in mixture with fir. None of the other native conifers can be recommended for use, and no native hardwoods occur locally, However, two hardwoods are indigenous to this general region which might be used, BLACK COTTONWOOD (Populous trichocarpa) and OREGON ASH (Fraxinus oregona). They are both suited to moist, loamy soil, and would do better than any other species on certain small areas. The cottonwood is a fast grower, gives a clear bole, and the wood is even now quite valuable for cooperage and will probably be used very extensively for pulp. The ash is also a fairly fast grower and the wood is used for small stock and also for lumber and commands a good price.

There are also several eastern species which are well suited to the natural conditions here and which yield very valuable products. Although planting them would be to a certain degree experimental, enough is known to be certain that they will yield a good return on the investment and the following species are recommended for use: EASTERN WHITE PINE (Pinus strobus). This is the only eastern conifer recommended. Its product is extremely valuable, it is a fairly fast grower, is well adapted to the same requirements as Douglas fir and should be planted in mixture with it, the same as the western white pine.

Several species of the hardwoods may be tried out. BLACK WALNUT (Juglans nigra). A fast grower, yielding the most valuable wood of any tree in the country. Should be planted on good, rich soil, in mixture with other species, preferably Oak. After once being started, it can be managed on a coppice system. HICKORY (Hicoria ovata and H. glabra). These two species should be the best of the hickories. They require deep, rich, fresh soil, and make a fairly fast growth after starting. They can later be managed on a coppice system, with a faster rate of growth. A peculiarity is that the fast growth sapwood is the more valuable and is greatly used for small stock, as tool handles, spokes, vehicle construction, etc. As no hickory grows on the coast, it should prove very valuable. YELLOW POPLAR (Liriodendron tulipifera) and BASSWOOD (Tilia americana) would prove valuable. Both are fast growers, prune themselves well and require a deep, fresh, fairly rich soil. The wood of both species is light, soft and straight grained. Yellow poplar is very valuable for many uses and commands a good market, while basswood is nearly as good, and also makes a good wood for pulp. In addition to these it might prove well to try some experimental work with some foreign species, though none are planned for now.

SECTION IV.

General Results.

The future returns to be derived from this work of reforestation may be divided into two main classes, which may be designated as "VOLUME" and "VALUE." Under the head of "Volume" will be considered the actual results in the form of timber produced, while under the head of "Value" will be considered the financial returns—what factors influence them and the aim that it is desired to attain. Following these two main heads will be a general summary of all results and benefits to be derived from this work, financial and otherwise.

Future Volume Returns.

It is, of course, necessary to be able to tell what amount of timber can be grown in any period of time upon any given site in order to forecast closely the future returns. Such work is done by the compilation of what are known as "Yield Tables," which give the amount of timber that can be grown at any period upon any site quality. Of course, individual tree species require individual yield tables. But little work of this kind has been done as yet in this country, as it involves a great deal of time and expense and the covering of a large territory in order to secure sufficient data to compile an accurate table.

However, the importance of Douglas fir, especially in its relation to the future for this very work of reforestation, is so well recognized that for several years past the United States Forest Service has been gathering data on its growth and has now compiled a very accurate set of yield tables. This work was first started by Mr. T. T. Munger and his results published in 1911 in Circular 175 of the Forest Service entitled "The Growth and Management of Douglas Fir In the Pacific Northwest." Since then the work has been still further carried on in greater detail by Mr. E. J. Hanzlik of the Forest Service and the result of his studies published under the title of "A Study of the Growth and Yield of Douglas Fir on Various Site Qualities In Western Washington and Oregon." The figures here given in Tables 1, 2 and 3, 4, 5 and 6 are those in Mr. Hanzlik's report and due acknowledgment of the work of the Forest Service is made at this time.

The work was carried on in western Washington and Oregon west of the Cascade Mountains. About 61 tracts were examined in over 35 different localities and, altogether, 598 sample plots were laid out and measured. The data compiled can therefore be taken as a good, fair average of the yield obtainable. The different site qualities as they were classified for this study are the ones that have been used in this report as mentioned in Section 1.

This study included all types of Douglas fir stands so long as they were pure, even aged, fully stocked and under 140 years of age. The figures indicate the average and not the maximum results which are obtainable and are therefore conservative when applied to proper site qualities. The results as given should approximate fairly closely the results obtainable when Douglas fir is properly managed; if any different, the results obtained, especially as regards quality, which, of course, can not be shown in the tables, should be somewhat better.

The yield tables mentioned are Tables 1, 2, 3, 4, 5 and 6, immediately following.

TABLE 1.

Average Yield for Even-aged Stands of Douglas Fir on Quality 1 Soils.

ALL TREES.

Age	Number of trees per acre	Basal area	D. B. H. of Average Tree	Height of Average Tree	Yield per Acre	Average growth per acre in each decade	Mean annual growth per acre
Yrs.		Sq. Ft.	Inches	Feet	Cu. Ft.	Cu. Ft.	Cu. Ft.
20	940	124	5.0	36.0	2,100		105
30	625	162	6.9	61.0	4,000	190	133
40	383	190	9.6	83.5	6,750	275	169
50	275	216	12.0	102.0	9,050	230	181
60	220	241	14.2	117.0	10,800	175	179
60	250	213	12.5	100.0	8,850	148	147
70	190	268	16.1	129.0	12,500	170	178
80	171	294	17.7	139.0	14,200	170	176
90	152	317	19.6	147.5	15,900	170	176
100	136	337	21.3	155.5	17,600	170	175
110	122	354	23.1	163.0	19,200	160	174
120	112	369	24.6	170.0	20,700	150	172
130	105	383	25.9	177.0	22,100	140	170
140	100	396	27.0	184.0	23,400	130	167

Note: Yield in cubic feet includes the contents of the whole stem of all the trees.

TABLE 2.

Average Yield for Even-aged Stands of Douglas Fir on Quality 1 Soils.

Age	Number of trees per acre	Basal area	D. B. H. of average tree	Height of average tree	Yield per acre	Yield per acre	Average annual growth per acre in each decade	Mean annual growth per acre
Yrs.		Sq. Ft.	In.	Ft.	Cu. Ft.	Ft.B.M.	Ft.B.M.	Ft.B.M.
20								
30	36	36	13.6	78.0	1,200			
40	84	96	14.5	98.0	4,000	16,500		413
50	118	159	15.7	115.0	7,500	30,000	1,350	600
60	125	199	17.1	126.5	9,500	44,000	1,400	734
70	128	241	18.6	136.0	11,500	56,500	1,250	807
80	125	265	19.7	144.0	13,500	70,000	1,350	875
90	122	299	21.1	152.0	15,400	85,000	1,500	945
100	117	320	22.4	159.0	16,900	100,000	1,500	1,000
110	111	340	23.7	165.5	18,400	111,500	1,150	1,013
120	105	358	25.0	172.0	19,850	120,500	900	1,003
130	98	370	26.3	178.5	21,250	128,000	750	985
140	93	386	27.6	184.5	22,700	135,000	700	965

Note: Yield in board feet includes only merchantable contents of diameter of 8 inches inside the bark.

TABLE 3.

Average Yield for Even-aged Stands of Douglas Fir on Quality 2 Soils.

ALL TREES.

Age	Number of trees per acre	Basal area	D. B. H. of Average Tree	Height of Average Tree	Yield per Acre	Average growth per acre in each decade	Mean annual growth per acre
Yrs.		Sq. Ft.	Inches	Feet	Cu. Ft.	Cu. Ft.	Cu. Ft.
20	940	94	4.3	31.0	1,730		87
30	625	132	6.3	54.5	3,230	150	118
40	425	163	8.4	76.5	5,450	222	136
60	250	213	12.5	100.0	8,850	148	147
50	312	190	10.6	90.5	7,370	192	147
70	223	235	13.9	108.0	10,000	115	143
80	210	256	15.0	114.0	11,150	115	139
90	203	276	15.8	120.0	12,250	110	136
100	198	292	16.4	126.0	13,400	115	134
110	196	305	16.9	132.0	14,500	115	132
120	194	316	17.3	137.5	15,650	110	130
130	192	325	17.6	143.0	16,650	100	128
140	190	334	18.0	148.0	17,500	85	125

Note: Yield in cubic feet includes the contents of the whole stem of all the trees.

TABLE 4.

Average Yield for Even-aged Stands of Douglas Fir on Quality 2 Soils.

Age	Number of trees per acre	Basal area	D. B. H. of average tree	Height of average tree	Yield per acre	Yield per acre	Average annual growth per acre in each decade	Mean annual growth per acre
Yrs.		Sq. Ft.	In.	Ft.	Cu. Ft.	Ft.B.M.	Ft.B.M.	Ft.B.M.
20								
30	24	22	12.9	78.0	600			
40	88	89	13.5	96.0	3,350	12,000		300
50	110	134	14.8	107.0	5,550	21,500	950	430
60	120	169	16.2	115.0	7,350	32,000	1,150	534
70	122	197	17.5	122.0	8,850	41,500	950	593
80	118	221	18.6	129.0	10,200	50,000	850	625
90	117	242	19.6	135.0	11,450	58,000	800	640
100	116	260	20.3	141.5	12,600	66,000	800	660
110	115	278	21.0	148.5	13,650	74,000	800	673
120	114	292	21.7	155.0	14,500	81,000	700	673
130	113	307	22.3	161.0	15,300	86,500	550	665
140	112	322	23.0	166.0	16,100	91,500	500	653

Note: Yield in board feet includes only merchantable contents of trees 12 inches or more in diameter at breast height, taken to a top diameter of 8 inches inside the bark.

TABLE 5.

Average Yield for Even-aged Stands of Douglas Fir on Quality 3 Soils.

ALL TREES.

Age	Number of trees per acre	Basal area	D. B. H. of Average Tree	Height of Average Tree	Yield per Acre	Average growth per acre in each decade	Mean annual growth per acre
Yrs.		Sq. Ft.	Inches	Feet	Cu. Ft.	Cu. Ft.	Cu. Ft.
20		79			1,320		66
30	1,630	109	3.5	44.0	2,500	118	83
40	775	134	5.6	59.0	4,200	170	106
50	515	157	7.5	70.0	5,650	145	113
60	362	178	9.5	79.0	6,700	105	112
70	286	196	11.1	86.0	7,650	95	109
80	253	211	12.4	92.5	8,570	92	107
90	238	225	13.2	99.0	9,520	95	106
100	233	237	13.6	105.0	10,350	83	103
110	228	246	14.0	111.0	11,100	75	101
120	224	254	14.4	116.5	11,750	65	98
130	219	261	14.8	122.0	12,250	50	94
140	214	267	15.1	127.5	12,700	45	91

Note: Yield in cubic feet includes the contents of the whole stem of all the trees.

TABLE 6.

Average Yield for Even-aged Stands of Douglas Fir on Quality 3 Soils.

Age	Number of trees per acre	Basal area	D. B. H. of average tree	Height of average tree	Yield per acre	Yield per acre	Average annual growth per acre in each decade	Mean annual growth per acre
Yrs.		Sq. Ft.	In.	Ft.	Cu. Ft.	Ft.B.M.	Ft.B.M.	Ft.B.M.
20								
30								
40	14	12	12.5	85.0	350			
50	65	63	13.5	94.0	2,500	9,500		190
60	93	108	15.0	103.5	4,350	16,500	700	275
70	96	144	16.6	112.0	6,000	25,500	900	364
80	98	171	17.9	120.0	7,400	34,000	850	425
90	100	196	19.0	128.0	8,600	42,000	800	467
100	101	213	19.8	135.0	9,600	49,000	700	490
110	100	226	20.4	140.0	10,500	55,500	650	505
120	99	236	20.9	148.0	11,250	60,500	500	504
130	97	244	21.4	154.0	11,950	64,500	400	496
140	96	251	21.8	159.0	12,600	67,500	300	482

Note: Yield in board feet includes only merchantable contents of trees 12 inches or more in diameter at breast height, taken to a top diameter of 8 inches inside the bark.

As one of the principal schemes of utilization is to consist of the marketing of the products obtained from thinnings, or intermediate cuts, made during the rotation, a great deal of study has been given to that particular subject. The results that have been worked out by the writer are original and along a somewhat new line, but are strictly legitimate and logical in their derivation and are also deemed conservative. The method of determination is as follows:

It will be noticed that in Column 2 of Tables 1, 3 and 5, showing the number of trees at each decade, the number, of course, decreases as the stand increases in age, due to the natural death rate among the young trees. Under ordinary conditions in a primeval forest these trees would stand until decayed or blown down and would by their presence materially retard the development of the rest of the stand. In this work it is on a basis of such dying trees that the thinnings are estimated.

As these trees will naturally be the most poorly developed in the stand at each decade, the estimate of their size must be smaller than the size of the average tree. So, in order to be conservative, they were figured on the following basis: Average diameter of trees to be removed as thinnings, 2 inches less than the diameter of the average tree at the same period as shown in Column 4 of the yield tables. The average height has been taken as 20% less than the height of the average tree as shown in Column 5. This is necessary, as these dead trees are naturally the most suppressed. Their volume according as their size fits them for different uses, as mining timbers, piling, etc., has been computed from the volume tables for Douglas fir as given in Circular 175 of the Forest Service. Also in the earlier periods only about 75% of the number of trees which die are reckoned as being merchantable. These reduced estimates both as to size and number of the trees that are to be used as thinnings insure the conservatism of the estimate. The amounts of these thinnings are given in Table No. 7, as follows:

TABLE 7.

Yield Tables for Thinnings from Douglas Fir at Different Periods and on Different Site Qualities.

Age of Stand in Years	Number of Trees Removed in Thinnings	Diameter of Average Trees Removed as Thinnings	Height of Average Trees Removed as Thinnings	Total Volume Removed as Thinnings at each Decade
		NO. 1 QUALITY SITES.		
30	120	5.0	45	3 cords
40	100	7.5	65	2,500 ft. mining timber
50	50	10.0	80	2,000 ft. mining timber
60	30	12.0	90	1,500 ft. mining timber

70	15	14.0	100	750 ft. piling
80	15	15.5	105	900 ft. piling
90	12	17.5	110	3,600 ft. B. M.
100	12	19.0	115	4,200 ft. B. M.
		NO. 2 QUALITY SITES		
30	100	4.5	40	2.5 cords
40	100	6.5	60	2,000 ft. mining timber
50	50	8.5	75	1,650 ft. mining timber
60	25	10.5	85	1,050 ft. mining timber
70	12	12.0	90	600 ft. mining timber
80	7	13.0	95	300 ft. mining timber
		NO. 3 QUALITY SITES.		
40	150	4.0	45	3.5 cords
50	125	6.0	55	1,250 ft. mining timber
60	70	7.5	60	1,850 ft. mining timber
70	30	9.0	65	1,000 ft. mining timber
80	15	10.5	70	675 ft. mining timber

Note: First thinning under each case to be made only if market conditions show that it will not prove an expense.

The discussion of prices for the products of these thinnings and their influence on the intensity with which such cuts will be made are taken up in the following subject of "Future Values," as are also the prices for the final cuts at different times.

As far as regards other species that may be grown on the area, little that is definite as concerns their rate of growth can be told. This is especially true as regards such species as are not native to this region, for example: black walnut, hickory, yellow poplar and eastern white pine. It is known, however, that their rates of growth in their natural regions are very good and all indications are such as to lead to the belief that they will do well here.

Douglas fir, however, will form by far the largest part of the new forest and it is sufficient for demonstrating the value of the work to show its results. Data for yield tables on these other species is being constantly compiled and within a few years enough will be known about them to make fairly accurate forecasts of what their future yields should be.

FUTURE VALUES.

Under this head there will be a discussion of future stumpage values with the factors influencing them as well as they can be forecast; a statement of the cost of this special work to the city; a statement of the financial returns that should be derived from it, and a comparison of the cost of this work to the city and to the private individual, showing the great balance in favor of the city.

Some people at this time seem to doubt that there will be a greater increase in the use of wood in the future, or even as great a use as at present, and believe that prices therefor will not materially advance. It is desired to quote the following, merely as an example:

The population of Great Britain and Ireland during the period from 1880 to 1900 increased by about 20%. During the same time the increase in imports of timber was about 45%. In other words, every head of population of 1900 used more timber than 20 years earlier. Germany produced in 1880 about as much timber as she required; in 1899 she imported 4,600,000 tons (probably about 3,000,000,000 feet B. M.), valued at about $68,000,000, and her imports are rapidly increasing, although the yield capacity of her own forests is much higher now than it was formerly.

The increase of population in these countries is not nearly so great as in our own. In fact, our own increase of population is so rapid that even if no more timber is used per capita in the future than at present, our annual cut must be increased in order to meet the increased demand.

Sir William Schlich, the most noted European authority on forestry, states that: "The United States of America will not much longer be a genuine exporting country, since they import already almost as much timber from Canada as they export. The only countries which are able to supply coniferous timber for export on a considerable scale are Russia, Sweden, Norway, Austria and Canada. As these countries have practically to supply the rest of the world, and as the management of their forests is far from satisfactory, the question of supplying light pine and fir timber, which forms the very staff of life of the wood industries, must become a very serious matter before many years have passed. Unmistakable signs of the coming crisis are everywhere visible to all who wish to see, and it is difficult to over-state the gravity of the problem!"

The State of Washington at present leads all states in the amount of timber cut, the annual cut averaging about 4,500,000,000 feet B. M., or a little over 10% of the entire lumber cut of the United States. At such a rate, it will not be long before her forests will be practically gone. The influence of the Panama Canal will in all probability be such as to increase the rapidity of cutting. Times now are not as they were when the great forests of the Northern Lake States were being cut. Then the Pacific Coast, with its wealth of material, offered at low prices, furnished a supply which has since had the effect of keeping prices fairly low. When this timber is gone, there being no virgin supply to fall back upon, there will be an inevitable rise in price.

This may be demonstrated in several ways:

First, there may be made a comparison with the rise in prices of stumpage during the past, of which the following instances may be quoted:

Hemlock in Pennsylvania in 1865 was counted a waste product. Now it is worth from $6 to $8 per M. feet. Long leaf yellow pine in Missouri in 1880 was sold by the acre at an average price of 10 cents per M. feet. In 1899 it was worth $1.00 per M. and in 1907 was worth $3.15 per M.

But perhaps the best example of all is that of the famous white pine in the Upper Lake States. In 1866 it could be bought for $1.25 to $2.50 per acre. In the early seventies it reached $1.00 per M.; about 1890 it brought $5.00 per M.; about 1900, $8.00 per M.; and in 1910 the average price in upper Michigan was $14.50 per M. Douglas fir in this region presents a case almost analogous to that of the white pine, and it is safe to say that a similar relative increase in prices will occur here. In fact, it is more than probable that the increase in prices will be much greater, due to the fact, before mentioned, that there is no fresh supply to fall back upon.

Second, by computing the cost to an owner of acquiring timber now and holding it for a future market at, say, 80 years from now. Good stumpage cannot be bought at the present time for less than $2.00 per M. feet. If held 80 years and the owner desires to make 5% interest on his investment, the stumpage price at that future time would have to be $99.12 per M. and this figure does not take into account any such item as taxes, protection, etc. Including these items, the price would have to be at least $125 per M. As this shows the utter impracticability of holding timber now acquired, it follows that such timber must be cut, and cut soon, in order to realize a profit. This will result in the early removal of practically all of the enormous stands of mature timber now existing in Oregon and Washington.

Future supplies must then be obtained by the operations of reforestation, or the growing of timber.

The **third** method of comparison is based upon the fact that in the future timber must be grown, as is any other crop, to supply the increasing demands of the future. The cost to private parties, of growing timber, is greater than the cost to the city or to other municipal corporations. Approximately four-fifths of the timber in the United States now belongs to private owners. If the same ratio obtains in the future, the price of timber will be determined largely by the cost to private parties of the growing of the timber. If the land suitable for reforestation eventually becomes to a greater extent the property of municipal corporations, the price of timber will more nearly approach the cost to municipal corporations of the growing of the timber, plus a reasonable percentage for profit. In any case, if the use of timber continues, its market price in the future will represent the cost to the municipality of growing the timber, plus an amount varying from a reasonable percentage of that cost to an amount representing the difference in the cost to the private owner over and above that to the municipality. In order to show what this difference of cost may be, the following Tables Nos. 8, 9 and 10 are submitted. The remarkable advantage to the municipality, it may be pointed out, lies in the fact of its being relieved of the payment of taxes:

TABLE 8

Per Acre Cost of Growing Timber Upon Cedar River Watershed Under Municipal Ownership

Average cost of stocking, $9.25 per acre. Administration and protection, 5 cents per acre per annum. No taxes. No initial land cost. Interest rate, 4½%, compounded annually. Final yield taken as average of Qualities 1, 2 and 3, in proportion as they occur on the lower watershed, viz.: 8% No. 1, 70% No. 2, and 22% No. 3 site quality.

(1) Age in Yrs.	(2) Cost of Stocking, with accumulation of interest	(3) Administration and protection with interest	(4) Total Cost of Work at each decade	(5) Yield in Ft. B. M. per acre	(6) Cost per M. Ft. for growing timber
40	$ 53.80	$ 5.35	$ 59.15	9,600	$ 6.16
50	83.54	8.92	92.46	19,500	4.74
60	129.75	14.47	144.22	29,500	4.89
70	201.50	23.09	224.59	39,100	5.74
80	312.93	36.47	349.40	48,000	7.28
90	485.97	57.26	543.23	56,600	9.60
100	754.69	89.54	844.23	64,900	13.01

The following Tables Nos. 9 and 10, showing cost of growing timber under private ownership, are based upon the assumption that the land is composed of 50% of No. 1 quality site, and 50% of No. 2 quality site. This gives a greater yield per acre than in the case of the lands in the lower watershed, as in Table No. 8. It is believed that this is a fair assumption, for the reason that the returns from No. 3 quality sites would be too low to warrant reforestation under private ownership.

TABLE 9.

Per Acre Cost of Growing Timber Under Private Ownership.

Cost of land, $2.50 per acre. Average cost of stocking, $7.50 per acre (exceptionally low). Interest rate, 5%, compounded annually. Taxes at 1% of real value (substantially the present rate of taxation). Up to 40 years, real value is considered $10 per acre; thereafter, it is considered as the real cost of growing the timber, with a re-assessment every ten years. Administration and protection, 5 cents per acre per annum. Yields are average of No. 1 and No. 2 quality sites.

(1) Yrs.	(2) Cost of land and stocking with accumulated interest	(3) Administion and protection with accumulated interest	(4) Taxes	(5) Total cost of growing timber at each decade	(6) Final yield at each decade in Ft. BM.	(7) growing timber Cost per M. ft for
40	$ 67.90	$ 6.04	$ 12.08	$ 86.02	14,200	$ 6.06
50	112.17	10.47	30.81	153.45	25,700	5.97
60	184.29	17.68	69.80	271.77	38,000	7.15
70	301.76	29.43	148.19	479.38	49,000	9.79
80	493.11	48.56	302.00	843.67	60,000	14.06
90	804.80	79.73	598.36	1,482.89	71,500	20.74
100	1,312.51	130.50	1,161.50	2,604.51	83,000	31.38

It will be observed from Table No. 9 that the general property tax takes an increasing proportion of the total cost, and must sooner or later force the cutting of the timber.

It is believed that the present system of taxation, as applied to standing timber, is inequitable and must give place to a system requiring the payment of the tax upon timber when the timber is harvested. This tax will fall at a time when the owner is best able to pay, and will not have the tendency to force the owner to cut before the timber has reached the most profitable cutting stage.

For the purposes of comparison, Table No. 10 has been computed in accordance with the above system of yield tax. With the interest rate at 5%, the final tax must be 20% to yield a return equivalent to a 1% annual tax.

TABLE 10.

Cost of Growing Timber under Private Ownership.

Cost of land, $2.50 per acre. Average cost of stocking, $7.50 per acre (exceptionally low). Interest rate, 5%, compounded annually. No annual tax, but final tax equivalent to 20% of final yield. Administration and protection, 5 cents per acre per annum. Yields are average of Nos. 1 and 2 quality sites.

Age in Yrs.	Cost of land and stocking with accumulated interest	Administion and protection with accumulated interest	Taxes	Total cost of growing timber at each decade	Final yield at each decade (80% of real yield) in Ft. B. M.	Cost per M. ft. for growing timber
40	$ 67.90	$ 6.04		$ 73.94	11,400	$ 6.49
50	112.17	10.47	20%	122.64	20,600	5.95
60	184.29	17.68	of	201.97	30,400	6.64
70	301.76	29.43	final	331.19	39,200	8.45
80	493.11	48.56	yield.	541.67	48,000	11.28
90	804.80	79.73		884.53	57,200	15.46
100	1,312.51	130.50		1,443.01	66,400	21.73

In preparing these tables, no reduction of cost by reason of revenues from thinnings has been made, for the reason that the receipts from thinnings may be expected to vary with the location of the reforested lands with respect to markets, and with the topography and physical condition of the lands. The values given in the tables are relative values for comparative purposes.

For the purpose of estimating the probable returns to the city from the sale of timber grown upon the lower watershed, a series of stumpage values at periods of ten years has been used in this report, as follows:

TABLE 11.

Years.	Stumpage Value Per M. Ft. B. M.
40	$ 4.00
50	5.00
60	6.00
70	8.00
80	9.00
90	10.00
100	11.00

For the purpose of comparing the estimated stumpage values given in Table No. 11, with the cost of growing timber under different conditions, the following Table No. 12 is introduced:

TABLE 12.

(1) Age in Years.	(2) Estimated stumpage value per M. ft. B. M.	(3) Cost to city of growing timber per M. ft. B. M.	(4) Cost under private ownership, present system of taxation, per M. ft. B. M.	(5) Cost under private ownership, modified yield tax system, per M. ft. B. M.
40	$ 4.00	$ 6.06	$ 6.06	$ 6.49
50	5.00	4.74	5.97	5.95
60	6.00	4.89	7.15	6.46
70	8.00	5.74	9.79	8.45
80	9.00	7.28	14.06	11.28
90	10.00	9.60	20.74	15.46
100	11.00	13.01	31.38	21.73

Expressed in percentages of the cost to the city of growing timber, the results are as follows:

TABLE 13.

(1) Age in Years.	(2) Estimated stumpage value per M. ft. B. M.	(3) Cost to city of growing timber per M. ft. B. M.	(4) Cost under private ownership, present system of taxation, per M. ft. B. M.	(5) Cost under private ownership, modified yield tax system, per M. ft. B. M.
	Per cent	Per cent	Per cent	Per cent
40	64.9	100	98.4	105.4
50	105.5	100	125.9	125.5
60	122.7	100	146.2	135.8
70	139.4	100	170.6	147.2
80	123.6	100	193.1	154.9
90	104.2	100	216.0	161.0
100	84.6	100	241.2	167.0

Expressed in percentages of the estimated stumpage values, the results are as follows:

TABLE 14.

(1) Age in Years.	(2) Estimated stumpage value per M. ft. B. M.	(3) Cost to city of growing timber, per M. ft. B. M.	(4) Cost under private ownership, present system of taxation, per M. ft. B. M.	(5) Cost under private ownership, modified yield tax system, per M. ft. B. M.
	Per cent	Per cent	Per cent	Per cent
40	100	154.0	151.5	162.2
50	100	94.8	119.4	119.0
60	100	81.5	119.2	110.7
70	100	71.8	122.4	105.6
80	100	80.9	156.2	125.3
90	100	96.0	207.4	154.6
100	100	118.3	285.3	197.5

It will be evident from an inspection of the above tables that the stumpage values estimated at different periods in the future are conservative. These figures, however, do not take into account any returns that may be derived from thinnings and it is there that the secret of profit lies. Other parties may not be able to make such thinnings on account of a lack of a proper location as regards market and, as shown later, the lower watershed has an ideal location for this purpose. But even leaving this subject out of the consideration, it can be seen that the city can grow timber much cheaper than private parties. And it is the cost of such growing that will to a large extent influence future stumpage prices.

In fact, the main tendency of the future to hold down stumpage prices will come from the following sources: First, the National forests, from which, by the present practice of storing up vast quantities of timber, the United States will, in the future, be in a position

[illegible]

the results [illegible]

INDUSTRIES AND ALLIED ECONOMIC SUBJECTS.

The first point is, of course, the accessibility of the area, close to a large city. [illegible] [illegible] product can be marketed in a [illegible]. In addition [illegible] the watershed is more than thirty miles from Seattle, the freight rates to the market are very low. In addition there are several small towns, which are generally great timber consumers, all within radius of a short shipping distance, so that from the point of freight rates there will be no difficulty in securing an ample market.

Two railroads now cross the area, the Chicago, Milwaukee & St. Paul Ry. from east to west and the Green River branch of the Northern Pacific from north to south, while the Columbia & Puget Sound Railway terminates at the town of Taylor in the northwestern part of the watershed. These railroad connections afford ample shipping facilities from all parts of the area and it will not be necessary to have to locate a large central shipping point.

While there is ample market for all of the lumber to be taken out as the final cut at the end of the rotation period, the great advantage in the location of this area is its proximity to a ready market for all such material as will be taken out in the intermediate cuts or thinnings. And it is the revenue from the sale of such material that gives the opportunity for a large profit on the enterprise.

In other operations this material is generally disposed of as pulp wood, firewood, railroad ties, etc., at a fair price. Here, however, there is a large market in the future for the consumption of this material in a form which will bring in a much better price. It is indeed doubtful if there is any other location in the State which affords the opportunity for the full utilization of such material at as good prices as can be obtained here. The point referred to is the demand for mining timbers in this immediate vicinity.

On the watershed itself there is the town of Taylor, with the works of the Denny-Renton Clay & Coal Co. This offers a ready market right at hand for a partial consumption of some of the mining timbers. At Renton there are the mines of the Puget Sound Traction, Light & Power Co. At New Castle, Ravensdale and Black Diamond there are also several coal mines belonging to the Northwestern Improvement Co., and the Pacific Coast Coal Company, and there exist within the immediate vicinity great deposits of coal at present unused, awaiting the time when economic conditions will justify their development. All these mines are within a short shipping distance of the watershed and all can be reached by the Columbia & Puget Sound Railway, the Northern Pacific Railway, or the Chicago, Milwaukee & St. Paul Railway. This fact of being able to ship direct from Taylor to these mines by the Columbia & Puget Sound Railroad is one of the main reasons, as mentioned earlier, for starting the first operations on the lands in the vicinity of Taylor.

to sell this timber cheaper and so keep the price down, provided that policy is adopted by the Government. Second, the state lands, in case the state, as is now proposed, reforests its logged-off lands and sells its future product. The ability to sell cheaper in both these cases comes from the fact that the National and State Government are able to secure money at a low rate of interest and, above all, pay no taxes. The City of Seattle will be, however, in a position to meet competition from such sources. Third, importations from foreign countries, whose timber supply is at present undeveloped. Such imports will, to a certain degree, tend to keep prices low, but cannot prevent a rapid rate of increase in stumpage prices at some time in the relativelv near future.

Bearing in mind the facts and figures given above, the estimated stumpage values as used in forecasting future results given in Table No. 11 will be seen to be a minimum. There is no doubt in the minds of those who are conversant with the economic conditions of the timber supply of the country and of the increasing demand for timber that these figures are ultra conservative. It is the writer's personal opinion from his knowledge of the markets in this vicinity that the future financial returns will, in all probability, be at least 20% greater than those given in the money yield tables. It may be remarked here that a peculiarity which has since become an axiom in European forestry, where time has had a chance to prove all theories, is this: "All predictions as regards future prices, however wild at the time, have always and invariably proven too low."

Following such a line it might be well to quote here a few examples of European stumpage prices. Silver fir and Norway spruce in the famous Black Forest in Germany, in regions difficult to log, and standing only about 40,000 feet to the acre at 100 years of age, are valued at from $18.00 to $30.00 per M., according to location. Scotch pine in the valleys, accessible, but in comparatively poor stands, is worth $25.00 to $30.00 per M. The finest white oak in the Spessart Mountains is worth from $100.00 to $175.00 per M. and is sold by the individual log. Southern yellow pine lumber imported from New Orleans sells in Mannheim at $50.00 per M. While it is not at all meant to suppose such prices here, these figures are given merely to show at what prices stumpage may be sold eventually, and, in comparing all factors, to show the conservatism of the figures used in this report.

As the future value of the timber depends to a large extent upon the location of the area and its proximity to the market, this subject has been given due consideration, and a description of the area, from an economic standpoint, is here given.

INDUSTRIES AND ALLIED ECONOMIC SUBJECTS.

The first point is, of course, the accessibility of the land, which, to a large extent, determines whether or not the product can be marketed at a profit. No shipping point in this lower watershed is more than forty miles from Seattle, so the freight rates to the market will be very low. In addition there are several small towns, which are generally great lumber consumers, all within radius of a short shipping distance, so that from the point of freight rates there will be no difficulty in securing an ample market.

Two railroads now cross the area, the Chicago, Milwaukee & St. Paul Ry. from east to west, and the Green River branch of the Northern Pacific, from north to south, while the Columbia & Puget Sound Railway extends to the town of Taylor in the northwestern part of the watershed. Such railroad connections afford ample shipping facilities from all parts of the area and it will not be necessary to have to locate a large central shipping point.

While there is ample market for all of the lumber to be taken out as the final cut at the end of the rotation period, the great advantage in the location of this area is its proximity to a ready market for all such material as will be taken out in the intermediate cuts or thinnings. And it is the revenue from the sale of such material that gives the opportunity for a large profit on the enterprise.

In other operations this material is generally disposed of as pulp wood, firewood, railroad ties, etc., at a fair price. Here, however, there is a large market in the future for the consumption of this material in a form which will bring in a much better price. It is indeed doubtful if there is any other location in the state which affords the opportunity for the full utilization of such material at as good prices as can be obtained here. The point referred to is the demand for mining timbers in this immediate vicinity.

On the watershed itself there is the town of Taylor, with the works of the Denny-Renton Clay & Coal Co. This offers a ready market right at hand for a partial consumption of some of the mining timbers. At Renton there are the mines of the Puget Sound Traction, Light & Power Co. At New Castle, Ravensdale and Black Diamond there are also several coal mines belonging to the Northwestern Improvement Co., and the Pacific Coast Coal Company, and there exist within the immediate vicinity great deposits of coal at present unused, awaiting the time when economic conditions will justify their development. All these mines are within a short shipping distance of the watershed and all can be reached by the Columbia & Puget Sound Railway, the Northern Pacific Railway, or the Chicago, Milwaukee & St. Paul Railway. This fact of being able to ship direct from Taylor to these mines by the Columbia & Puget Sound Railroad is one of the main reasons, as mentioned earlier, for starting the first operations on the lands in the vicinity of Taylor.

As to the future consumption of mining timbers by these companies, there is no doubt of the market afforded by them. That timber must be used for this work is admitted, and already the source of the future supply is a subject of some speculation. Interviews with men of these companies have brought forth the opinion that there is no doubt of the future market for this class of material, and that the prices for it will steadily increase.

At about sixty years it may pay better to take out the material in the form of piling, and there will always be a ready market for such material here in Seattle. It may also develop in the future that the prices of certain specific products may rise to such a degree as to make it more profitable to make these thinnings in other forms, as railroad ties, pulp wood, etc. If such should be the case, such arrangements can easily be made and the only effect on the financial returns would be to increase them, for unless it did mean such an increase the present idea of cutting mining timbers would be adhered to.

Another factor also of great importance is the extent to which the area is already opened up by logging roads. Old railroad grades, skid roads, fore and aft roads, pole chutes, etc., are found in all parts of the area, having been put in when the timber was originally logged. In addition there are the railroad grades being used by the lumber companies now operating, and there will also be the grades and roads that they will put in in the future.

As transportation charges, which include all the original cost of the construction of such grades, are perhaps the heaviest and most important of all expenses that have to be borne in logging, it can be seen what a great saving it means to have these grades already constructed. Some repair work will have to be done on them when it comes time to use them, but all location expenses will be done away with, and the repair cost will be comparatively low. Indeed, this item of these roads being already in, will mean a saving of thousands of dollars and will render it remunerative to reforest some areas which would otherwise be a doubtful proposition as to whether or not they would pay.

Besides their utility when logging is to be done they will be of present use in the reforesting work itself, as they make the area accessible for pack horses, and in some places for teams, and so facilitate the transportation of material in the field. And also they afford a most excellent basis for the development of systems of fire lines.

The question of labor is one that is, of course, difficult to discuss with any relation to the future, but it is safe to say that with all the small towns in the immediate vicinity, together with the facilities of getting men in Seattle, that there will be no trouble in that regard. The work requires a comparatively small force of men, and those only for a relatively short time, so that the labor question presents no difficulties.

Indeed, considering the two main factors, first, that all routes of transportation in the area are already or will be, to a certain extent, well developed, and, second, that there is right at hand the very best kind of a market for the future products, with shipping facilities leading direct to these markets, the situation of the area is the very best, from the viewpoint of its economic location upon the future financial returns.

ESTIMATE

of Probable Financial Returns to the City of Seattle from the Reforestation of the Lower Watershed.

In the preparation of this estimate, consideration is given to all items bearing upon or influencing the final cost to the city. The revenue to be derived from the timber to be removed at varying intervals for the purpose of thinning the stand is first computed as to each class of sites and the value of the standing timber remaining upon the land at each period after the thinning is also estimated. These figures are given in Table No. 15, following:

TABLE 15.

Showing future values of thinnings and the final cut, at different decades and on all site qualities, according to future stumpage prices as already forecast, per acre.

For Thinnings.

Years.	Total volume of thinnings per acre.	Future price per unit.	Total value of thinnings.
	NO. 1 QUALITY SITE		
30	3 cords		
40	2,500 lin. ft. mining timber	¾c per lin. ft.	$18.75
50	2,000 lin. ft. mining timber	1c per lin. ft.	20.00
60	1,500 lin. ft. mining timber	1¼c per lin. ft.	18.75
70	750 ft. piling	3c per lin. ft.	22.50
80	900 ft. piling	3½c per lin. ft.	31.50
90	3,600 ft. B. M.	$9.00 per M.	32.40
100	4,200 ft. B. M.	10.00 per M.	42.00
	NO. 2 QUALITY SITES		
30	2.5 cords		
40	2,000 lin. ft. mining timber	¾c per lin. ft.	$15.00
50	1,650 lin. ft. mining timber	1c per lin. ft.	16.50
60	1,050 lin. ft. mining timber	1¼c per lin. ft.	13.12
70	600 lin. ft. mining timber	1½c per lin. ft.	9.00
80	300 ft. piling	3½c per lin. ft.	10.50

NO. 3 QUALITY SITES

40	3½ cords	
50	1,250 lin. ft. mining timber—1c per lin. ft.	$12.50
60	1,850 lin. ft. mining timber—1¼c per lin. ft.	23.12
70	1,000 lin. ft. mining timber—1½c per lin. ft.	15.00
80	675 lin. ft. mining timber—1¾c per lin. ft.	11.81

For Final Cut.

Years.	Total volume of final cut per acre.	Future price per M. ft. B. M.	Total value of final cut per acre.
	NO. 1 QUALITY SITES		
40	16,500 ft. B. M.	$ 4.00	$ 66.00
50	30,000 ft. B. M.	5.00	150.00
60	44,000 ft. B. M.	6.00	264.00
70	56,500 ft. B. M.	8.00	452.00
80	70,000 ft. B. M.	9.00	630.00
90	85,000 ft. B. M.	10.00	850.00
100	100,000 ft. B. M.	11.00	1,100.00
110	111,500 ft. B. M.	12.00	1,338.00
120	120,500 ft. B. M.	12.50	1,506.25
	NO. 2 QUALITY SITE		
40	12,000 ft. B. M.	$ 4.00	$ 48.00
50	21,500 ft. B. M.	5.00	107,50
60	32,000 ft. B. M.	6.00	192.00
70	41,500 ft. B. M.	8.00	332.00
80	50,000 ft. B. M.	9.00	450.00
90	58,000 ft. B. M.	10.00	580.00
100	66,000 ft. B. M.	11.00	726.00
110	74,000 ft. B. M.	12.00	888.00
120	81,000 ft. B. M.	12.50	1,012.50
	NO. 3 QUALITY SITE		
50	9,500 ft. B. M.	$ 5.00	$ 74.50
60	16,500 ft. B. M.	6.00	99.00
70	25,500 ft. B. M.	8.00	204.00
80	34,000 ft. B. M.	9.00	306.00
90	42,000 ft. B. M.	10.00	420.00
100	49,000 ft. B. M.	11.00	539.00
110	55,500 ft. B. M.	12.00	666.00
120	60,500 ft. B. M.	12.50	756.25

Table No. 15 shows the computed receipts and values on an acre basis for each site quality. In order to determine the probable receipts and values over the entire area of the lower watershed, in proportion to the relative areas of each site quality, Table No. 16 has been prepared. showing these figures with reference to an acre of average quality.

TABLE 16.

Showing the average receipts from thinnings and the average value of the final stand, at various decades, compiled from the values given in Table 15, and based on the fact that the lower watershed contains 8% of No. 1 Quality Sites, 70% of No. 2, and 22% of No. 3.

Years.	Average receipts from thinnings per acre.	Average value of final stand per acre.
40	$12.00	$ 38.88
50	15.90	97.70
60	15.77	177.30
70	11.40	313.44
80	12.47	432.72
90	2.59	566.40
100	3.36	714.78
110		875.16
120		995.62

Combining all elements of cost, with interest at 4½ per cent, compounded annually, computed at each ten years period, and deducting the value of the thinnings at each decade, the actual investment value at each period is shown on Table No. 17. There is also given the stumpage value of the standing timber at each period, the net profit or loss to the city and the equivalent net annual revenue per acre of average quality in the lower watershed.

TABLE 17

Showing Itemized Statement of all Costs and Receipts per Average Acre at Each Decade for Entire Lower Watershed.

(1) Age of stand in years.	(2) Summation of total cost of growing timber at each decade	(3) Summation of value of cash receipts from thinnings with interest.	(4) Summation of actual cost of investment at each decade.	(5) Stumpage value of final yield at each decade considered as an asset.	(6) Profit or loss if final cut should be made at any particular period of 10 years.	(7) Equivalent net annual revenue if final cut should be made at any particular 10 yr. period.
	Per acre.	Per acre.	Per acre.	Per acre.	Per acre.	Per acre.
40	$ 59.15	$	$ 59.15	$ 38.88	—$20.27	
50	92.46	18.63	73.83	97.70	+ 23.87	$0.134
60	144.22	53.63	90.59	177.30	86.71	0.300
70	224.59	107.78	116.81	313.44	196.63	0.426
80	349.40	185.08	164.32	432.72	268.40	0.368
90	543.23	306.80	236.43	566.40	329.97	0.288
100	844.23	480.48	363.75	714.78	351.03	0.196
110	1,311.68	751.40	560.28	875.16	314.88	0.113
120	2,037.62	1,166.92	870.70	995.62	124.92	0.029

Note.—For statement of items composing column 2, see columns 2 and 3, and compare with column 4 of Table 8.

An inspection of Table No. 17 will show that the greatest net annual revenue per acre is at the expiration of 70 years. Therefore, the cutting of the timber at approximately that period would result in the greatest profit to the city.

At 70 years, the value of the standing timber is $313.44 per acre. The value of the standing timber on the entire area of the lower watershed, amounting to 31,200 acres, would be $9,779,328.00. The net profit to the city, after deducting the accumulated cost of stocking the land, of the management of the work and the protection of the timber, is $196.53 per acre, or a total of $6,135,000 for the area of 31,200 acres included within the lower watershed.

It should be understood that this value is obtained by the use of the most conservative stumpage values as given in Table No. 11.

For the purpose of showing the returns to the city in case the actual stumpage values are substantially equivalent to the cost of growing timber under private ownership, Table No. 18 has been prepared.

TABLE 18.

Showing statement of costs and receipts per average acre at each decade, for entire lower watershed, based on the relative percentages for both thinnings and final cut, between the prices assumed and those given for the cost under private ownership for growing timber under the modified yield tax system, as shown in column 5 of Table No. 14, and applied to Table No. 16.

(1) Age of stand in years.	(2) Summation of total cost of growing timber at each decade. Per acre.	(3) Summation of value of cash receipts from thinnings with interest. Per acre.	(4) Summation of actual cost of investment at each decade. Per acre.	(5) Stumpage value of final yield at each decade considered as an asset. Per acre.	(6) Profit or loss if final cut should be made at any particular period of 10 years. Per acre.	(7) Equivalent net annual revenue if final cut should be made at any particular 10 yr. period. Per acre.
40	$ 59.15		$ 59.15	$ 63.06	$ 3.91	$0.036
50	92.46	$ 30.22	62.24	116.26	54.02	0.303
60	144.22	76.31	67.91	196.27	128.36	0.443
70	224.59	145.62	78.97	330.99	252.02	0.545
80	349.40	244.85	104.55	542.20	437.65	0.600
90	543.23	404.51	138.72	875.65	736.93	0.643
100	844.23	634.42	209.81	1,411.69	1,201.88	0.671

Table No. 18 shows that the greatest net annual revenue per acre, under the modified yield tax system, is secured by cutting the timber at some period slightly over 100 years.

UNIV. OF CALIFORNIA

For the purposes of comparison with the results given in Table No. 17, a computation of the net profit to the city at the 70-year period is made below.

The value of the standing timber at the 70-year period averages $330.00 per acre, or a total of $10,326,888 for the entire area of 31,200 acres in the lower watershed.

The net profit to the city, after deducting all accumulated costs, is $252.02 per acre, or a total of $7,863,024 for the area within the lower watershed.

Similarly, it may be shown that the estimated net profit to the city, in the case of the maximum stumpage values under the present tax system, at the 70-year period, is $9,426,000.

GENERAL CONCLUSIONS.

1. The proposition of reforesting the Cedar River Watershed is essentially practicable, and there will be no difficulty in creating the new forest. Under proper management and with thorough protection against fire, the future yields of timber should fully equal those forecast in the yield tables.

2. This reforestation will prove to be of very great benefit to the water supply of the city of Seattle, and on that account alone the work may be justified.

3. The work of re-stocking, thinning, logging and protection will provide profitable employment for numbers of men, without necessitating the establishment of a resident population within the watershed.

4. Values will be created where otherwise they would never exist. What is now a liability will be converted into an asset of very great value.

5. The creation of the new forest will add to the wealth of the city, and will promote the upbuilding and the advancement of the state.

6. The initial investment required for this work is exceedingly small, and the total cost will be distributed over a number of years.

7. The cost of the work will be returned to the City, together with a profit estimated at from about $6,000,000.00 to $9,000,000.00 by the expiration of a period of seventy years, with a possibility of greatly increased profits at a longer period, if stumpage values then exceed the lowest amount estimated in this report.

8. It is not now apparent that there is any argument against the reforestation of the lower watershed that can be sustained upon any ground other than the initial cost of the investment, and this cost is so small in comparison with the benefits to be derived from this work that it should not be given great weight.

RECOMMENDATIONS.

In view of all these facts and of the results of the studies and investigations carried on for four years past as embodied in this report, it is recommended that a definite plan for the reforestation of the lower watershed be worked out by skilled forest engineers, under the direction of a recognized authority upon reforestation.

That the City adopt such plan, when satisfactorily worked out and definitely determine upon a fixed policy to be pursued in carrying out this work.

And that then the work be undertaken and carried out in a regular and systematic manner, under the direction of the best qualified men obtainable for this purpose.

Respectfully submitted,
R. H. OBER,
Consulting Engineer
H. C. JOHNSON,
Forest Engineer

PAPERS PUBLISHED—Continued.

"THE NEW POWER PLANT OF THE OLYMPIA LIGHT & POWER COMPANY AT TUMWATER, WASHINGTON"—E. W. Cummings. Vol. V, No. 5. Price 25 cents.

"THE DELLES-CECILO CANAL"—W. C. Langfitt and Amos A. Fries. Vol. V, No. 6. Price 25 cents.

"RECENT DEVELOPMENTS IN ELECTRICAL ENGINEERING"—C. Edward Magnusson. Vol. V, No. 7. Price 25 cents.

"THE SOLUTION OF PRACTICAL PROBLEMS IN FIELD ENGINEERING"—S. N. Daugherty. "THE TRUE STATUS OF THE STEAM TURBINE"—Everett O .Eastwood. Vol. VI, No. 1. Price 50 cents.

"ECONOMIC CANAL LOCATION"—Theron A. Noble. "COST KEEPING AS AN AID IN MANAGING MEN"—Halbert P. Gillette. Vol. VI, No. 2. Price 50 cents.

"THE INFLUENCE OF THE TESTING OF MATERIALS UPON THE DESIGN OF STRUCTURES"—Almon H .Fuller. "DITCH CONSTRUCTION ON THE SEWARD PENINSULA"—J. A. Kelly. "MACADAM ROADS"—A. L. Valentine. "THE GREEN RIVER GRAVITY WATER SUPPLY FOR THE CITY OF TACOMA"—Frank L. Davis. Vol. VI, No. 3. Price 50 cents.

"THE NECESSITY OF STATE SUPERVISION FOR THE PROTECTION OF SOURCES OF PUBLIC WATER SUPPLIES"—H. Day Hanford. "THE SEWERAGE SYSTEM OF THE CITY OF BELLINGHAM"—Geo. M. Gerhard. Vol. VI, No. 4. Price 50 cents.

"TUNNELING ON THE ALASKA CENTRAL RAILWAY, AND A GENERAL DESCRIPTION OF THE ALASKA CENTRAL RAILWAY, WITH SOME OF THE METHODS USED IN LOCATING AND CONSTRUCTING THE LINE"—By George A. Kyle. Vol. VII, No. 1. Price 50 cents.

"MOUNTAIN RAILWAY LOCATION"—By J. J. Cryderman. Vol. VII, No. 2. Price 25 cents.

"CITY CONTRACTS"—J. C. Jeffery. "HYDRAULIC EXTENSION WORK OF THE SEATTLE MUNICIPAL LIGHT AND POWER PLANT"—J. L. Stannard. "THE ELECTRICAL EXTENSION WORK OF THE SEATTLE MUNICIPAL LIGHT AND POWER PLANT"—J. D. Ross. Vol. VII, No. 3. Price 50 cents.

"THE ENGINEER IN ALASKA"—James Lennox McPherson. "THE ECONOMIC DESIGN OF PRESSURE PIPE LINES FOR WATER POWER DEVELOPMENT"—Sterling B. Hill. Vol. VII, No. 4. Price 50 cents.

"SOME CONTROLLING FACTORS IN HYDRAULIC TURBINE DESIGN"—By C. W .Harris. Vol. VIII, No. 1. Price 50 cents.

"NOTES, HISTORICAL AND TECHNICAL, ON UNITED STATES WAR VESSELS"—By T. F. Ruhm, Naval Constructor, U. S. Navy. Vol. VIII, No. 2. Price 50 cents.

"THE CABLES OF THE WILLIAMSBURG BRIDGE, NEW YORK CITY"—By Isaac Harby. Vol. IX, No. 1. Price 25 cents.

"WOOD PIPE"—By Theron A. Noble. Vol. IX, No. 2. Price 50 cents.

"COLUMBIA RIVER BRIDGE"—By R. H. Ober. Vol. IX, No. 3. Price 50 cents.

"THE NEW SUBMARINES"—By Frank W. Hibbs. Vol. IX, No. 4. Price 25 cents.

"PUBLIC HEALTH LAWS AND THE ENGINEER"—E. J. McCaustland.

"BUILDING LAWS CONCERNING LOADS AND STRESSES"—John L. Hall. Vol. X, No. 1. Price 50 cents.

"REINFORCED CONCRETE DAMS"—By Bertram D. Lean. "PERMANENCE AS A FEATURE OF ENGINEERING WORKS"—By Wm. B. Ruggles. "THE PLACE OF THE CIVIL ENGINEER IN MODERN CIVILIZATION"—By A. H. Dimock. "THE PANAMA CANAL"—By A. W. Munster. "CONVENTION NOTES"—Vol. X, No. 2. Price 50 cents.

"THE HYDRAULIC RAM"—By Stirling B. Hill. Vol. X, No. 3. Price 25 cents.

"THE ORGANIZATION AND WORK OF THE MUNICIPAL PLANS COMMISSION OF THE CITY OF SEATTLE"—By D. W. McMorris. "REPORTS OF TENTH ANNUAL MEETING." Vol. X, No. 2. 25 cents.

"McCLELLAN IN RAILROAD SERVICE"—By Wm. B. Ruggles. "THE CROSSING OF EAST WATERWAY"—By Gen. H. M. Chittenden. Vol. XI, No. 2. Price 25 cents.

"STANDARD TABLES FOR ESTIMATING COST OF CONCRETE"—By Harrison S. Taft. Vol. XI, No. 3. Price 50 cents.

PAPERS PUBLISHED—Continued.

"THE HISTORY AND PRACTICE OF WOOD PRESERVATION"—By F. D. Beal. "LIMITATIONS"—By A. O. Powell. "THE INFLUENCE OF ARCHITECTURE ON MODERN ENGINEERING"—By G. R. G. Conway. Annual Report of Board of Directors. Vol. XII, No. 1. Price 50 cents.

"THE GROWTH OF THE CEMENT INDUSTRY OF THE PACIFIC COAST"—By Chas. A. Newhall. "DETERMINING THE DIAMETER OF PIPE LINE"—By C. W. Harris. Vol. XII, No. 2. Price 50 cents.

"A RETROSPECT AND A PROSPECT"—By R. H. Ober. "THE FRASER RIVER DELTA"—By G. R. B. Elliott. "PRINCIPLES OF EFFICIENCY FOR MINE MANAGEMENT"—By Glenville A. Collins. Vol. XII, No. 3. Price 50 cents.

"DESIGNING, BUILDING AND HANDLING OF CONCRETE FORMS"—By Harrison S. Taft. "THE HYDRO-ELECTRIC POWER SITUATION IN THE PACIFIC NORTHWEST AND ITS POSSIBILITIES"—By J. J. Wettrick. Vol. XIII, No. 1. Price 50 cents.

"RATIONALE OF BRIDGE DESIGN"—By Charles Evan Fowler. Vol. XIII, No. 2. Price 25 cents.

"A NORTHERN RAILROAD ENTRANCE TO SEATTLE"—By Gen. H. M. Chittenden. "SOME TYPES AND FEATURES OF MOVABLE BRIDGES"—By Samuel Murray. Vol. XIII, No. 3. Price 50 cents.

"STATE DEVELOPMENT AND THE ENGINEER"—By Joseph Jacobs. "STORAGE AND IRRIGATION DEVELOPMENT IN THE YAKIMA VALLEY"—By Charles H Swigart. "LOCATING AND ESTIMATING HIGHWAYS"—By F. W. Allen. "MINUTES OF TWELFTH ANNUAL CONVENTION"—By Redick H. McKee. Vol. XIII, No .4. Price 50 cents.

"MAINTENANCE OF EARTH AND GRAVEL ROADS"—By William J. Roberts. "COST OF TOPOGRAPHY FOR IRRIGATION WORK"—By Benjamin P. Little. "SPECIAL FEATURES AND COST OF SMALL IRRIGATION SYSTEM"—By Oliver M. P. Goss. "PEAT LANDS AND THEIR DRAINAGE"—By Vernon M. Eager. Price 50 cents.

"THE DELLES-CELILO CANAL" — W. C. Langfitt and Amos A. Fries.

"REFORESTATION OF THE CEDAR RIVER WATER SHED"—By R. H. Ober and C. H. Johnson. Price 50 cents.

PAT. JAN. 21, 1908

DEC 1939

DEC 4 '39

ED409
O2

345004

UNIVERSITY OF CALIFORNIA LIBRARY

THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW

AN INITIAL FINE OF 25 CENTS
WILL BE ASSESSED FOR FAILURE TO RETURN THIS BOOK ON THE DATE DUE. THE PENALTY WILL INCREASE TO 50 CENTS ON THE FOURTH DAY AND TO $1.00 ON THE SEVENTH DAY OVERDUE.

AUG 26 1947